Outline

- People Involved
- Introduction to NuMI Project
- Cavern Views, showing absorber & access labyrinth
- Absorber Goals
- Cross section view & History of cavern geometry
- Beam conditions, energy deposited, thermal studies
- Absorber Core Views
- Installation Costs
- Summary

People Involved

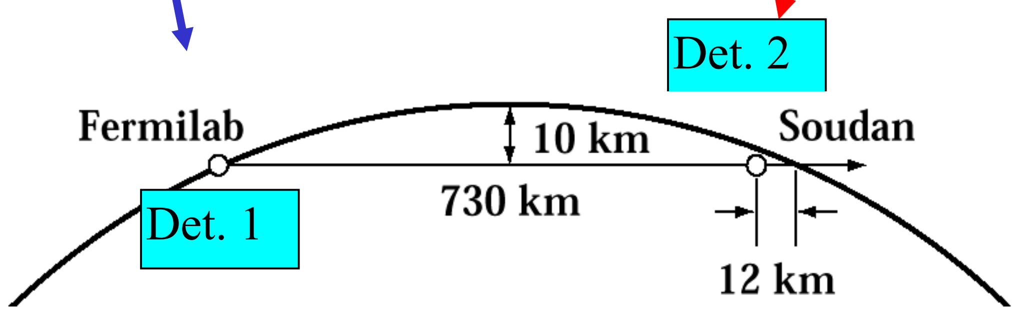
Name	**Group**	**Function**
A. Wehmann	BD NuMI	L3 Co-Manager
R. Bernstein	BD NuMI	L3 Co-Manager (6/1/01)
E. Villegas	PPD Engineering	mechanical design
R. Wands	PPD Engineering	thermal analysis
R. Williams	PPD Drafting	mechanical design
G. Koizumi	BD Beams	labyrinth design
N. Grossman	BD NuMI	radiation safety oversight
B. Baller	PPD Minos	L2 Co-Manager
A. Byon-Wagner	PPD Minos	L2 Co-Manager
L. Wai	Stanford U.	MARS studies
D. Pushka	BD NuMI	RAW system, integration
R. Ducar	BD NuMI	controls, integration

MINOS Experiment

Two Detector Neutrino Oscillation Experiment

Near Detector: 980 tons

Far Detector: 5400 tons



Neutrino Beam

Extract beam from Main Injector (kicker magnet and power supply)

Transport, focus 120 GeV proton beam (magnets, instrumentation, baffles)

Target (protons produce π^+) and radiation shielding

Magnetic horns to focus π^+, power supply, cooling water

Long evacuated pipe, π^+ decay to $\mu^+\nu$

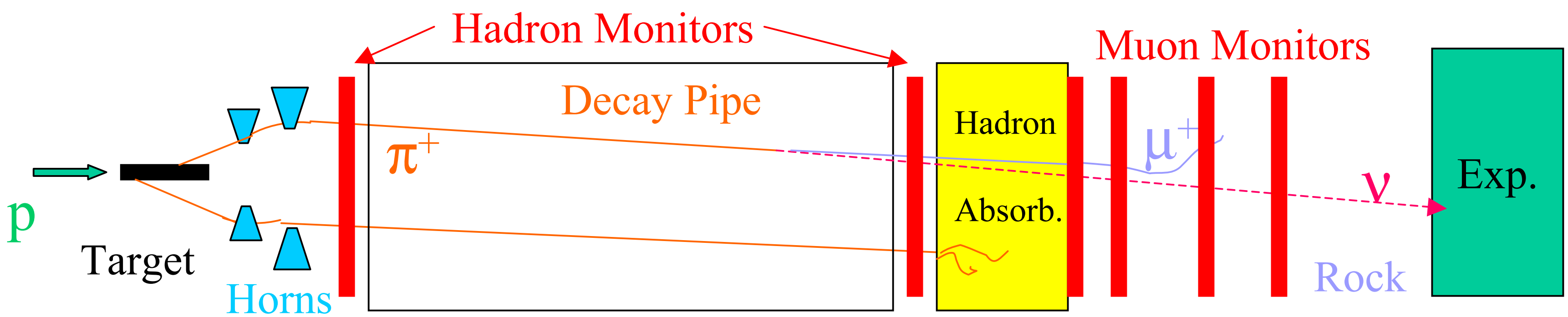
Left-over hadrons shower in hadron absorber

Rock shield ranges out μ^+

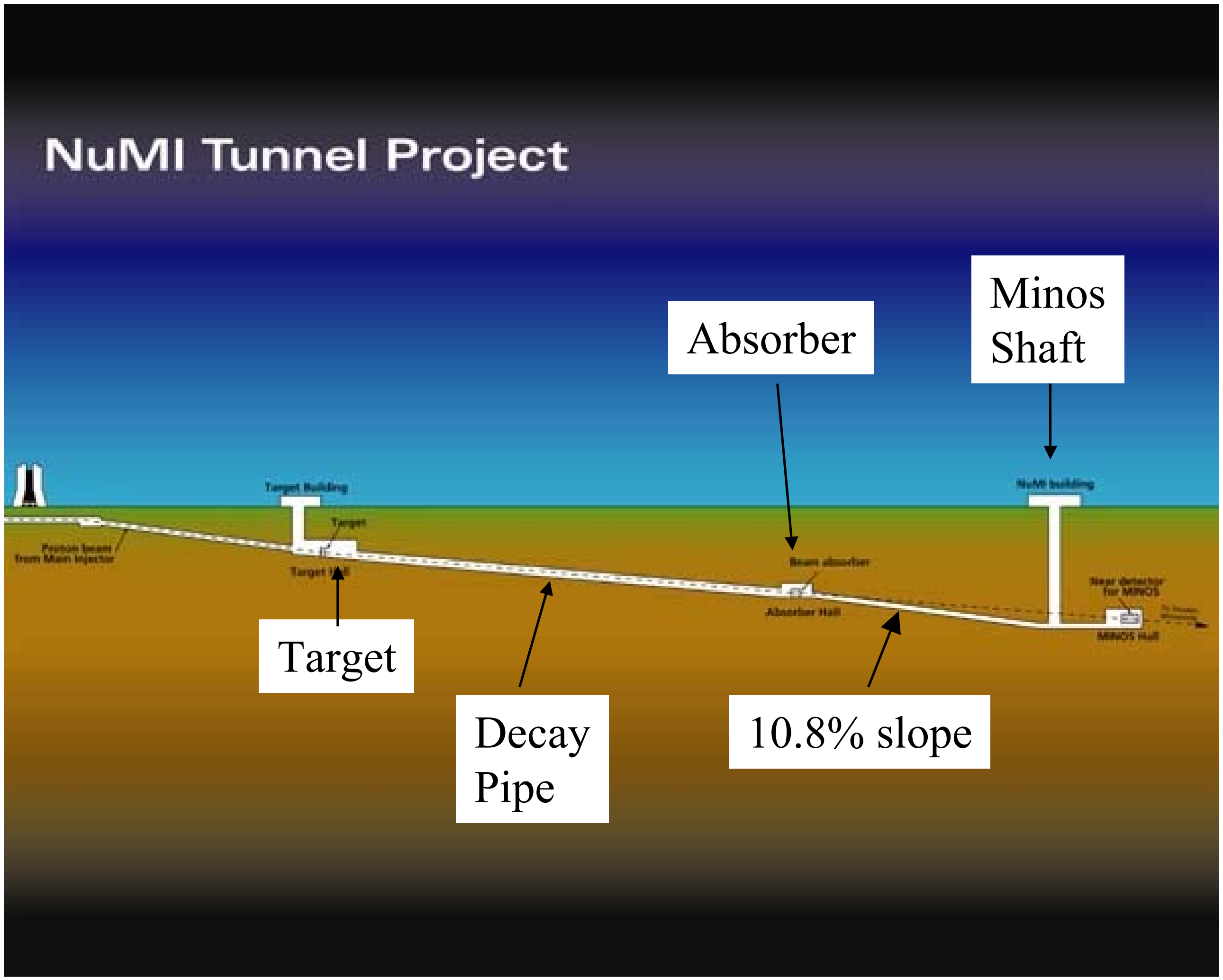
Detector chambers to monitor beam

ν beam travels through earth *to experiment*

Alignment, Integration, controls, permit ...



NuMI Tunnels



- 743’ surface elevation
- 405’ bottom of shaft
- 464.71’ Absorber Cavern

- Station 37+61 at shaft
- Station 31+00 at labyrinth exit

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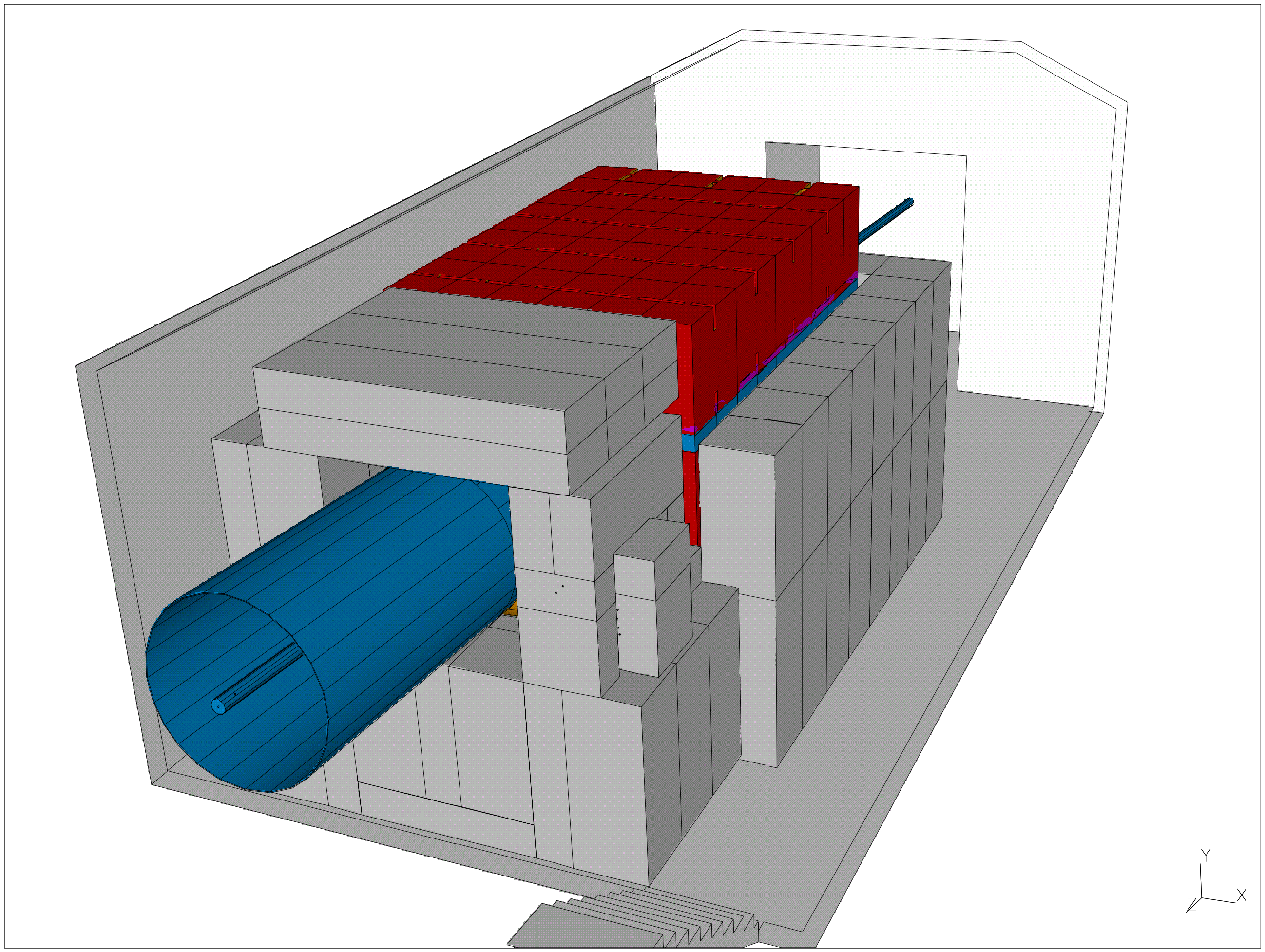
US view of Absorber Cavern

Absorber Review
A. Wehmann
June 12, 2001
WBS 1.1.4

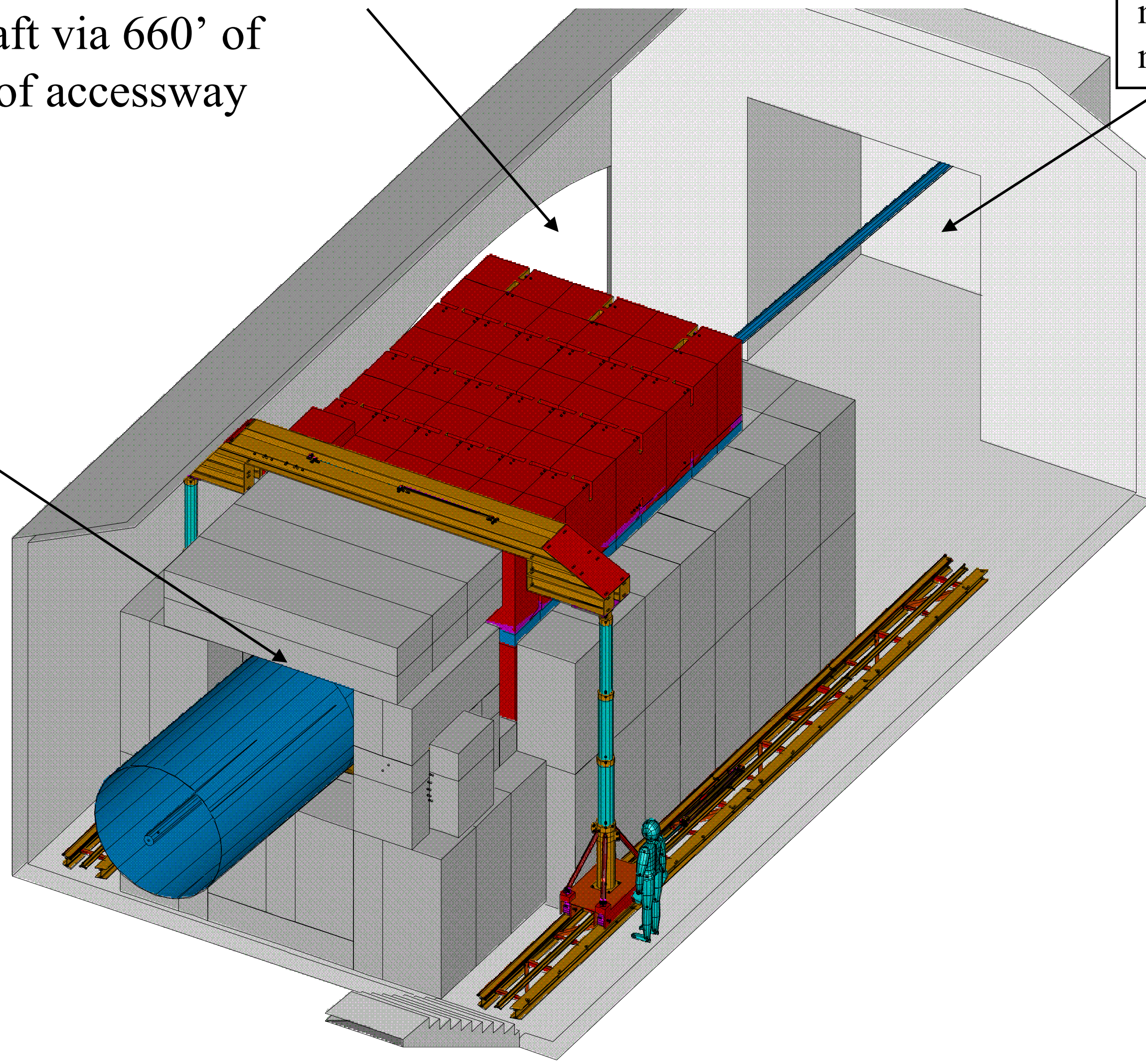


Plotted by villegas on 16-Mar-2001 , File: completed_absorber.pff

Absorber Cavern View

get here from MINOS shaft via 660’ of 10.8% slope ramp & 50’ of accessway

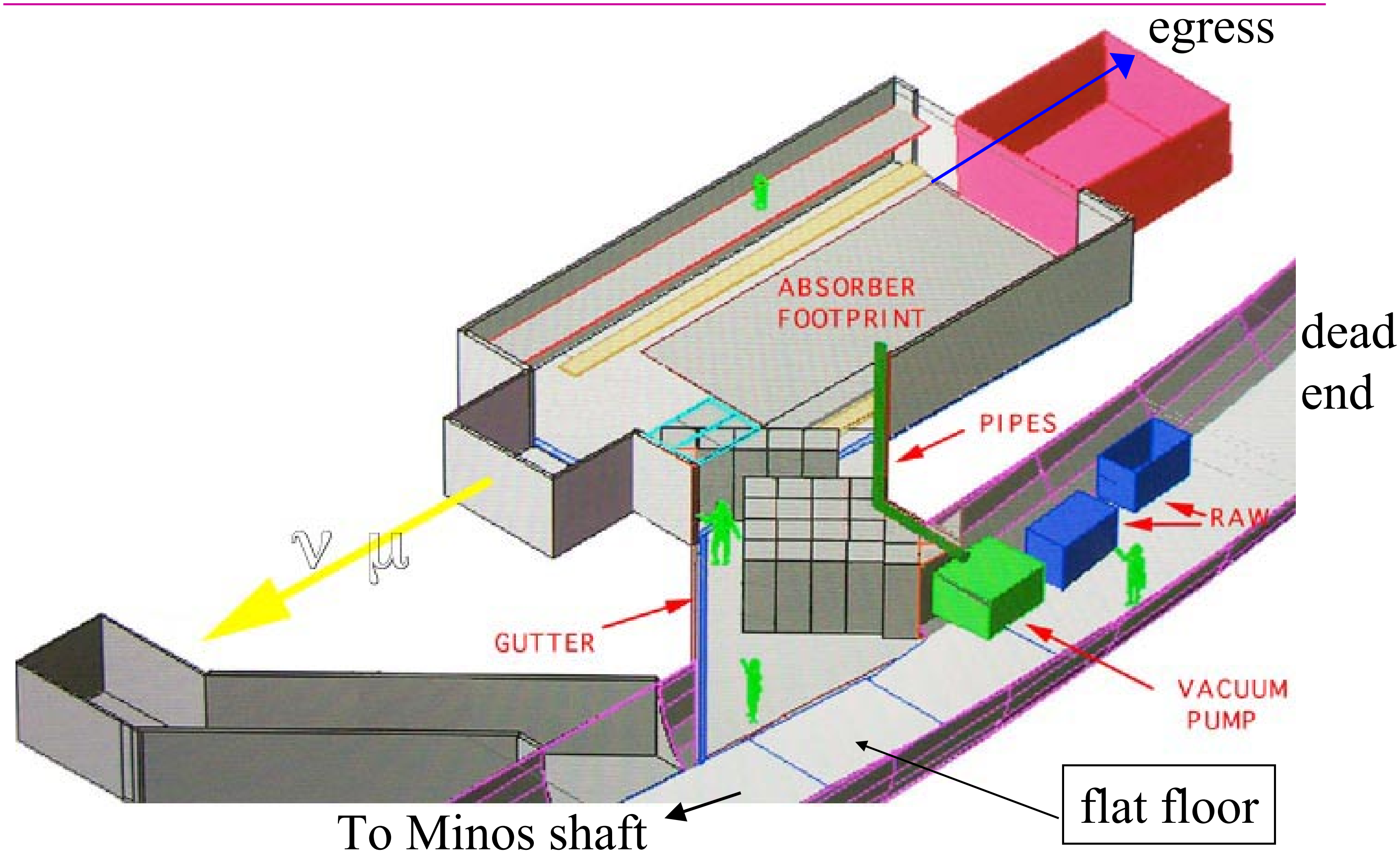
muon monitor



US shielding has penetrations for

- Decay Pipe Access Port
- DS Hadron Monitor
- Pipe to Vacuum Pump

Labyrinth & Environs



Absorber Goals

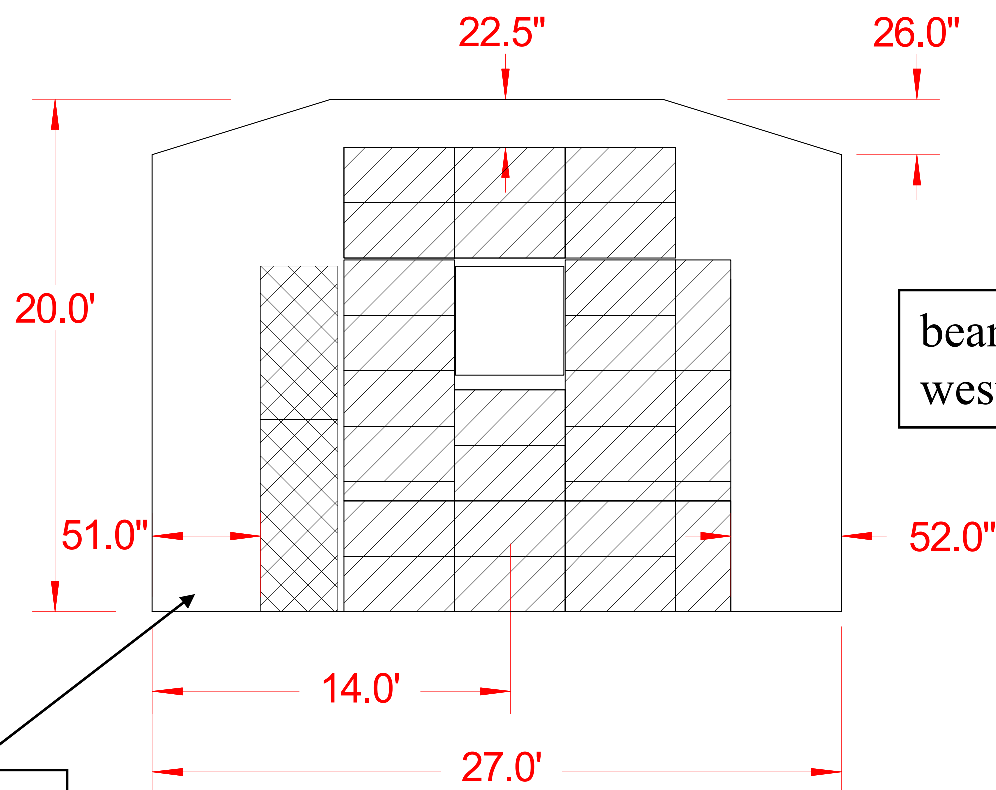
- Meet groundwater activation standards in walls of Cavern (< 20 pC/ml)
- residual radioactivity--aiming for 30 mRem/hr DS & Beam East, <100 mRem/hr elsewhere (10 hour cooldown)
- beam-on dose < 100 mRem/hr in region of exit labyrinth (allows beam-on access there)
- no core cooling failures during facility lifetime
- muon monitoring DS of absorber (LE beam)

Nancy Grossman will discuss first 3

Absorber Cross-Section

beam east

beam west



egress path

Looking Upstream

Cavern ceiling height is marginal—when the building crane was removed from WBS 1.2, the ceiling height was dropped from 32.5’ and floor remained at the same elevation

Steel block dimensions are

52” x 52” x 26”

positioning info

- beam is at 476.56’ elevation at entrance to cavern
- Absorber Cavern Floor is at 464.71’ elevation
- Difference is 11.85’ (142.2”)
- beam drops with pitch angle of -0.0583 mr (3.34321degrees, tan is -0.05824)

Cavern Geometry

- <11/98--Cavern width, length, floor height, position were fixed (core size 24” x 36”)
- ~7/99, core size increased to 42” x 48”
- ~12/99, building crane removed & ceiling lowered by12.5’
- 3/00, IHEP study recommended 52” x 52” core
- ~11/00, decision--too expensive to modify Cavern dimensions (to accommodate the IHEP side-extraction scheme for core modules)

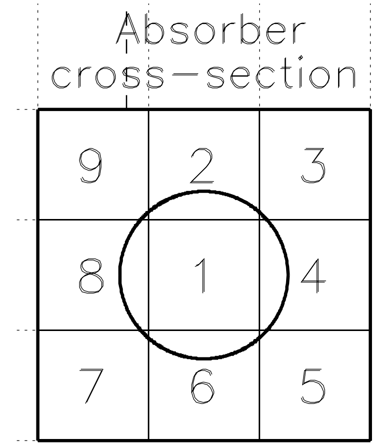
Beam Conditions

- Normal Operation
  - beam on target, RAW cooling system operational
  - $4 \bullet 10^{13}$ protons every 1.9 seconds (400 kW in beam)
  - studied in NuMI B-652
- Accident Conditions
  - Beam misses target (extremely unlikely with new baffle, target geometry)
    - studied in NuMI B-652 & by R. Wands
  - RAW cooling water failure (extremely unlikely with RAW cooling system controls)

Energy Deposited

Total energy in a beam	121.2 kJ
Energy of primary protons	99.7 kJ
Energy of secondaries: π, p	16.1 kJ
n, e, γ	5.4 kJ
Average beam power	64 kW

Table 2.1 from NuMI B-652



from Fig. 2.3, NuMI B-652

Part of the absorber	$0 \leq Z < 2.4$ m	$2.4 \leq Z < 3.7$ m
Core and subsequent steel	41.0 (Al)	5.7 (Fe)
Surrounding steel shielding	10.2	0.14

Table 2.2 from NuMI B-652
(units of kW)

Medium Energy beam geometry

Energy Deposited (con't)

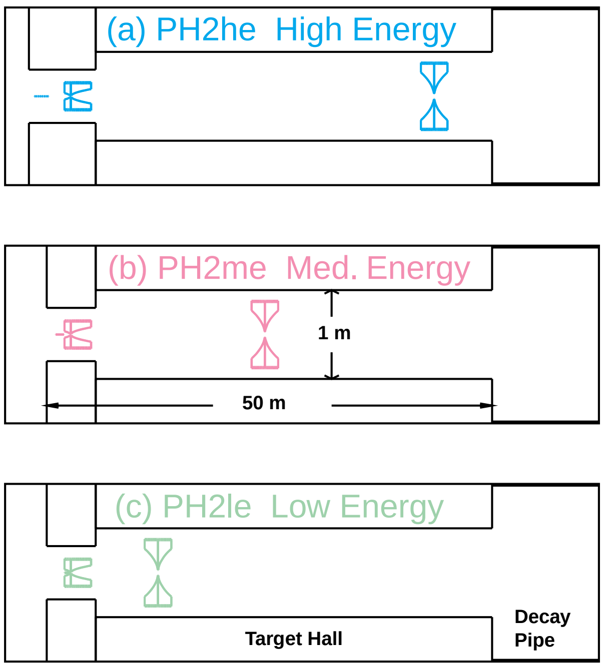
The Part of the Beam-line	LE–beam				ME–beam	
	OC	HH	BP	BP HH	OC	HH
Beam Absorber	59.7	27.3	4.99	10.1	60.0	35.1
aluminum core	41.4	16.6	2.34	6.61	40.2	22.4
steel shielding	18.3	10.7	2.65	3.45	19.8	12.7
Total	354.8	353.7	361.0	357.7	350.2	348.3
Leakage Power	11.7	15.4	11.7	14.4	14.1	19.0

Table 1: An average power (kW) deposited in different parts of the beam-line in case of the regular operation mode.

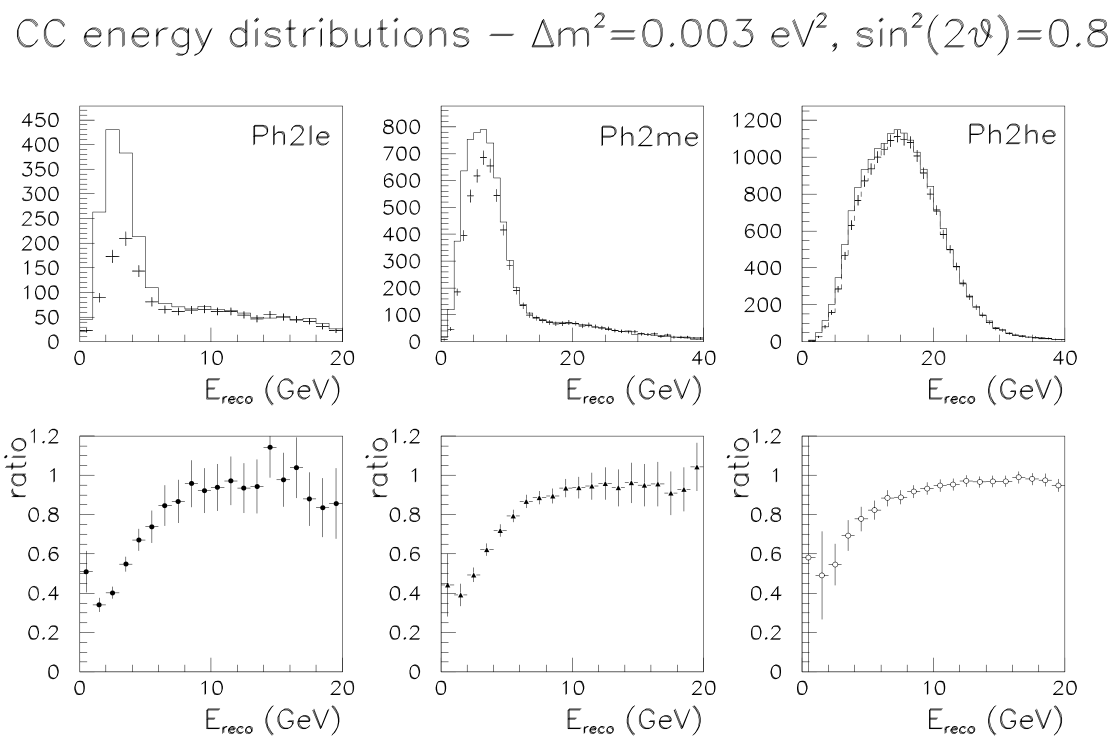
From NuMI B-709

OC - Original condition
HH – Hadron Host
BP – Beam Plug

Horn/Target Reconfiguration



At Soudan, without and with neutrino oscillations



Initial configuration is Low Energy Tune,
matching beam to expected oscillation region

Temperature, Stress

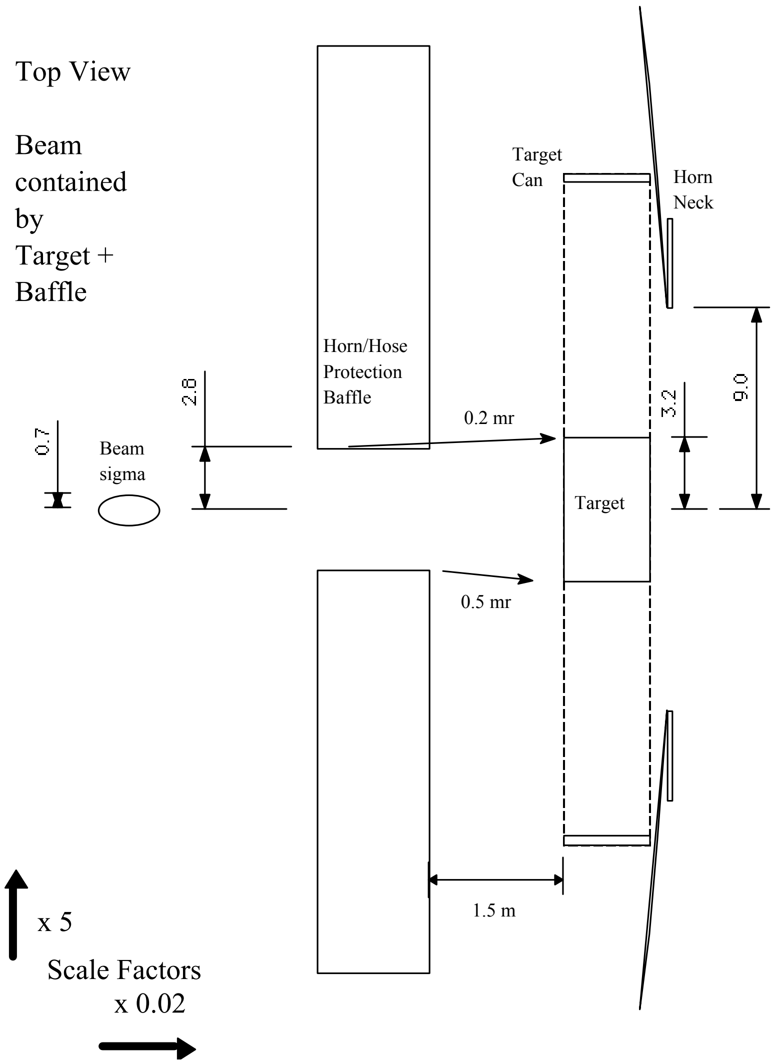
- Temperature of 60°C at center of Al module #4, after 3 ½ hours of normal beam (37 °C cooling water assumed), max. stress 13.2 Mpa
- Max. Temp. of 83°C for steel on sides (free convection at front face, 20°C ambient)
- Max. Temp. of 270°C for steel in core (1 mm gaps, convection at steel faces, 20°C ambient)

from NuMI B-652

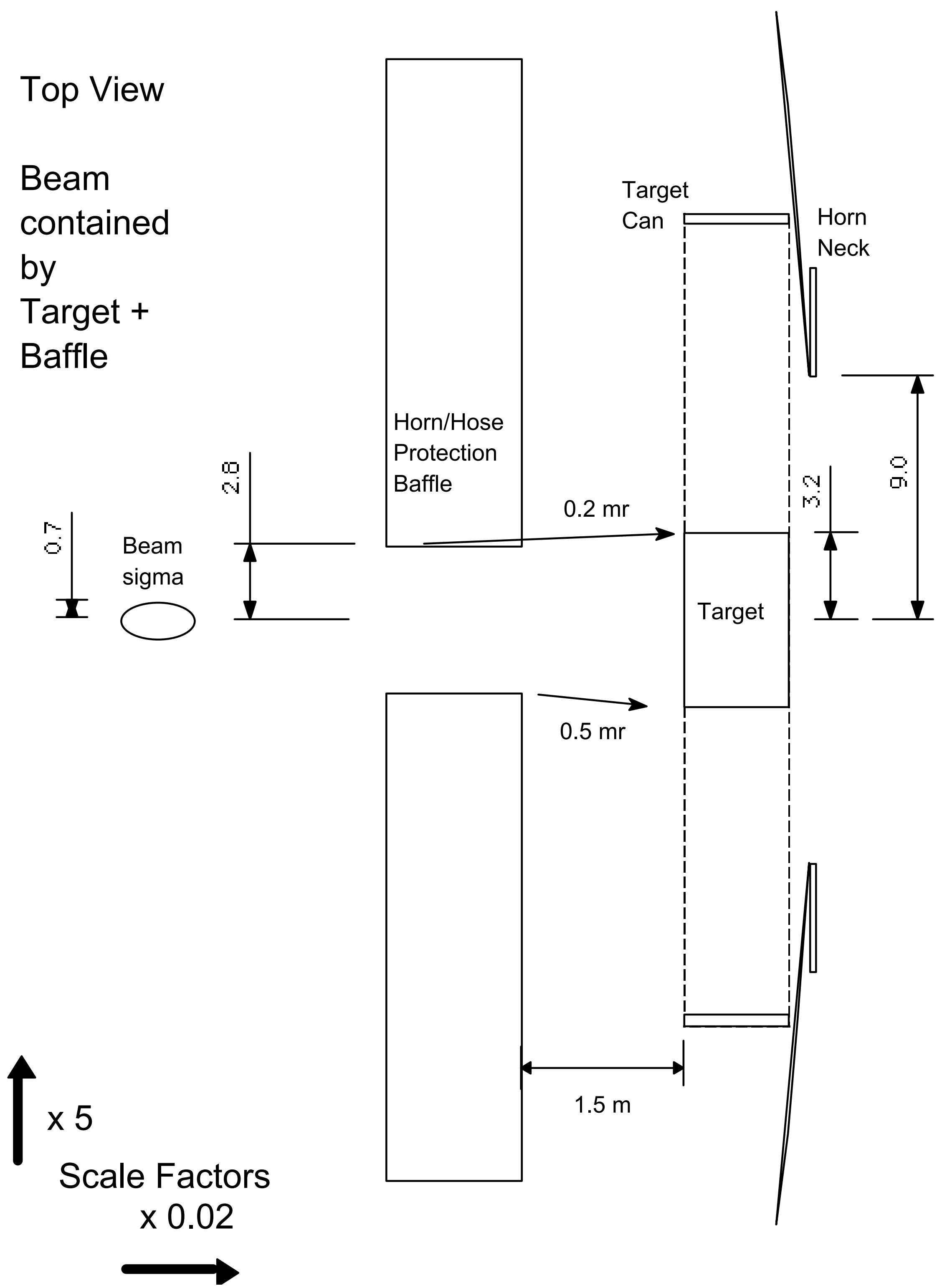
Bob Ducar will discuss the RAW cooling system

Bob Wands will discuss the study of 400 kW of beam power hitting the Absorber (very unlikely)

Baffle Protection System

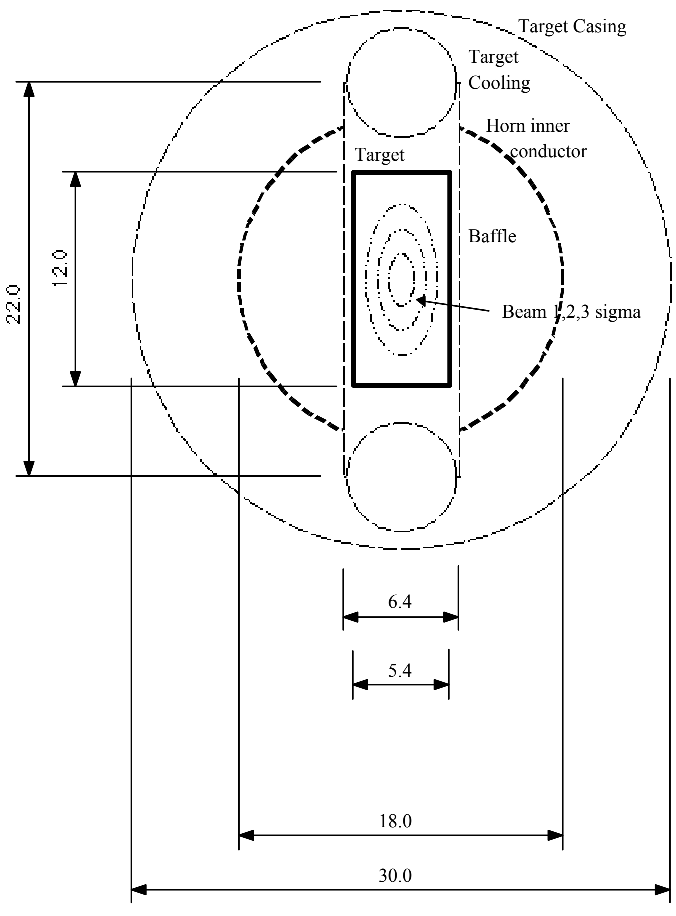


- original system protected horn inner conductors with 2 separated baffles
- new design has baffle closer to target, wider target
- beam extremely unlikely to bypass target with new design



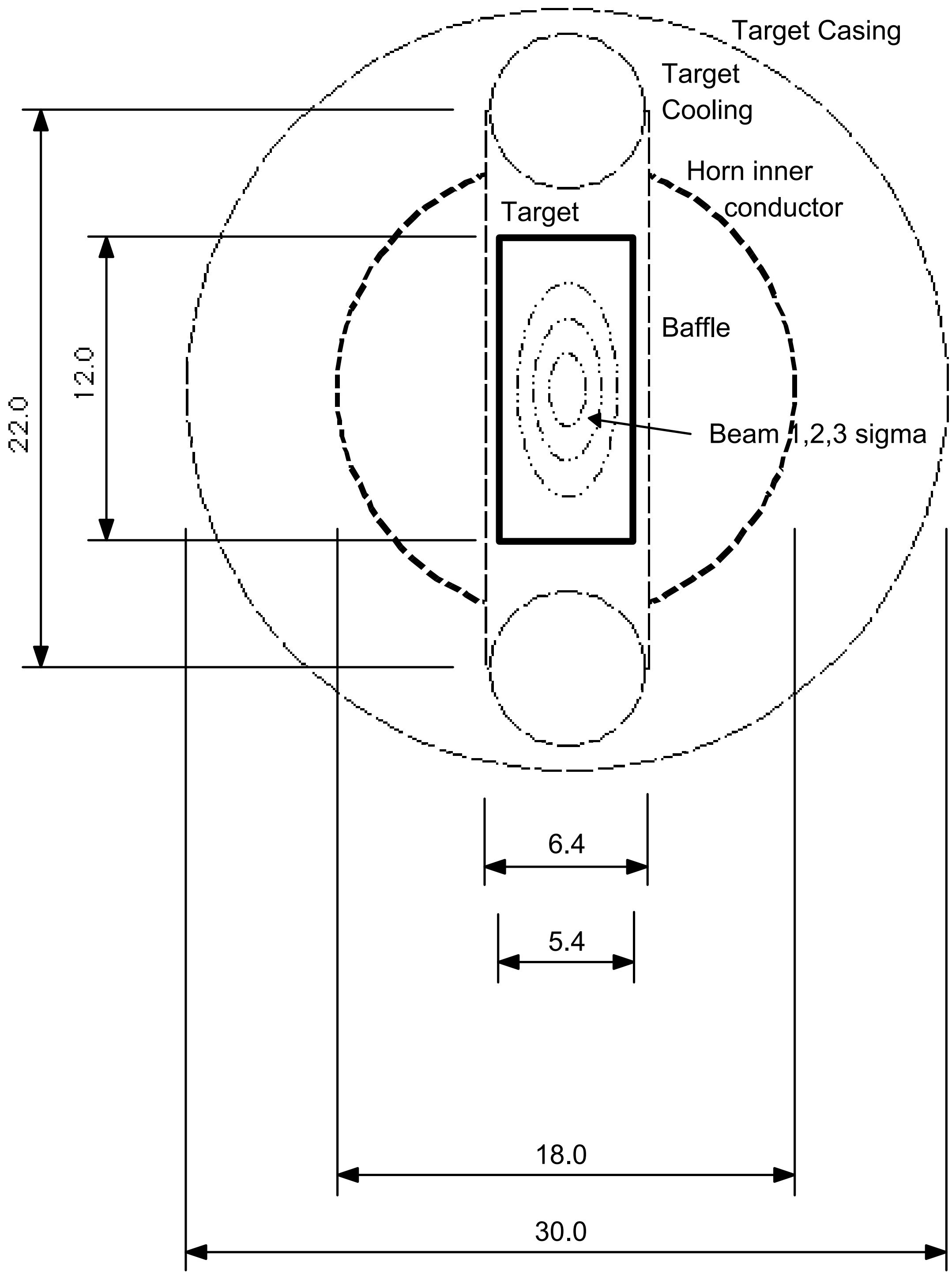
Top View
Beam contained by Target + Baffle
Horn/Hose Protection Baffle
Target Can
Horn Neck
Target
Beam sigma
0.7
2.8
3.2
9.0
0.2 mr
0.5 mr
1.5 m
x 5
Scale Factors
x 0.02

Baffle Protection System



Scale 4x, all units mm

- Beam view sees 5.4 mm wide opening in baffle (graphite)
- DS of baffle is 6.4 mm wide target



Scale 4x, all units mm

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Absorber Core

aluminum

steel

dual water circuits

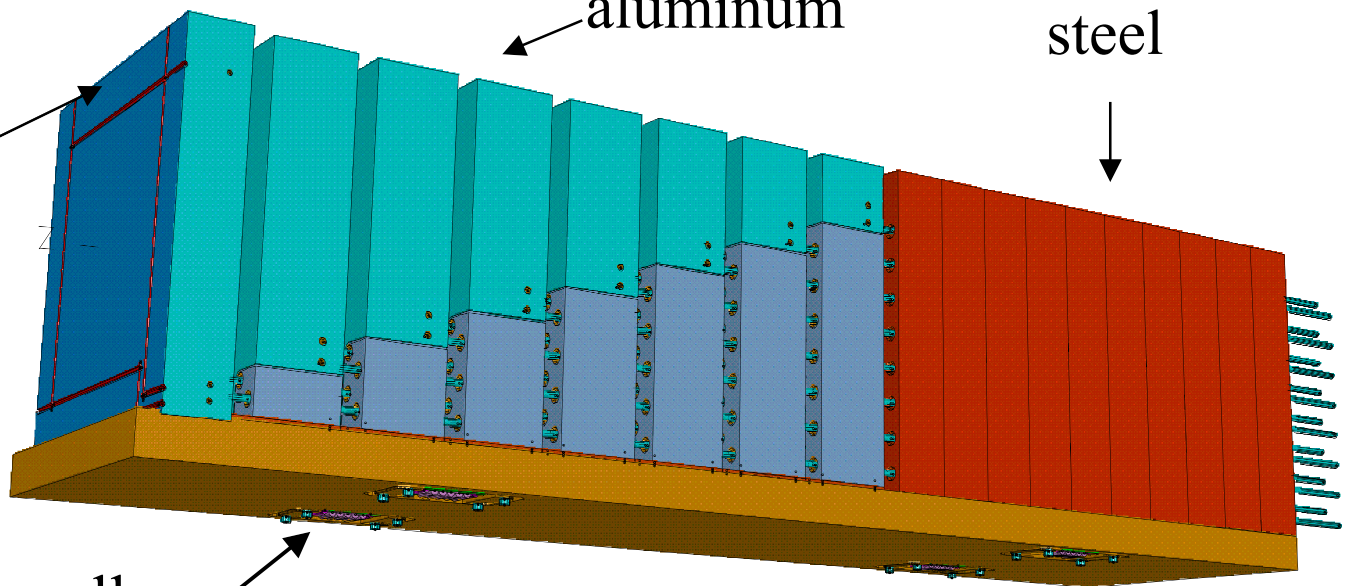


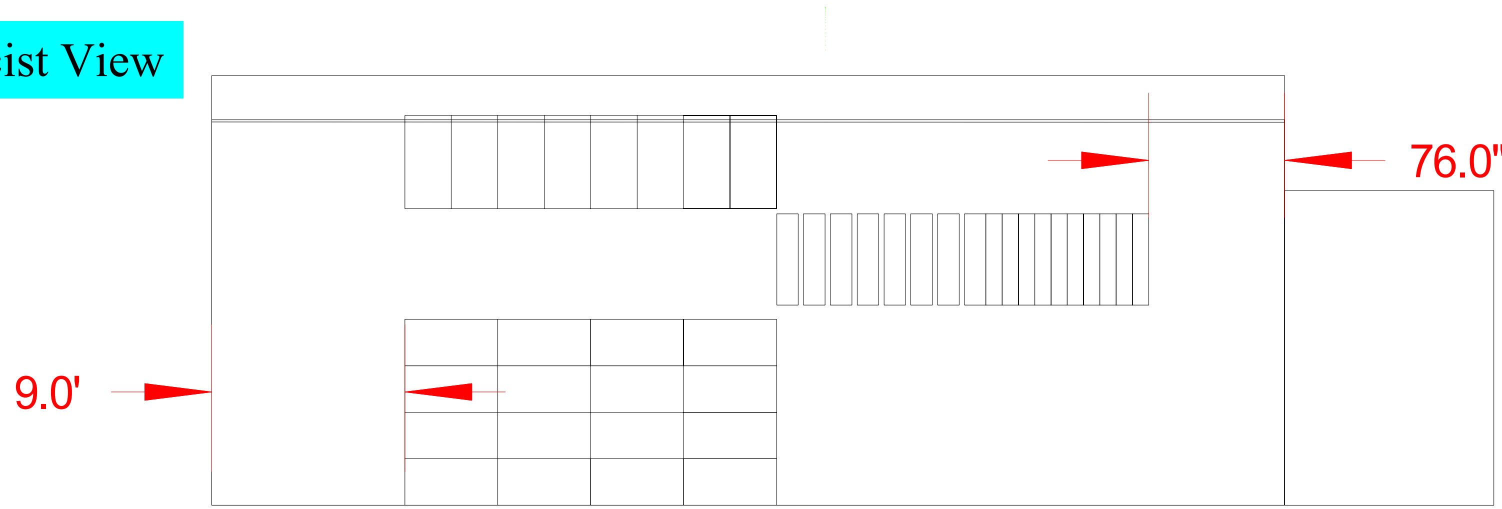
plate on rollers

one thermocouple per module (more on #3 or #4, for beam monitoring)

View from the other side will be shown by Ernie

Core Removed to Rear

Physicist View



- Installing in place is current choice
- Welded water connections and dual water circuits per module make it very unlikely to have to remove core
- Rollers & carrier plate in “scope”, other provisions for extraction & servicing are not

Cost Estimating

- Ernie Villegas, fabrication costs, engineering & drafting time
- me, installation costs

Presentation

Twin Lift, $8400 per month, several days of 3 man-crew to disassemble (3 pieces) and lower down shaft

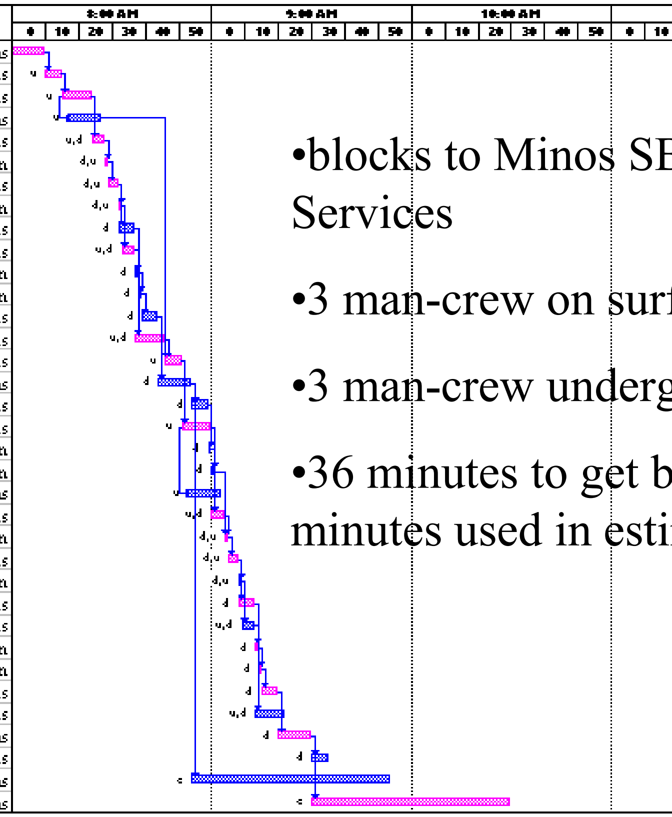
Extra ventilation costs not well known, ~21,000 cfm needed

refinement underway--as per May 22-24 DOE NuMI Review (to be frozen 7/15)

Block Staging Study

WBS 1.1.4 Study

Name	Finish	Dur
Move block#1 from hardstand into SB	8:10 AM	10 mins
Load Block #1 on crane at top of shaft	8:15 AM	5 mins
Lower Block #1 down shaft	8:24 AM	9 mins
Move block #2 from hardstand into SB	8:27 AM	10 mins
Transfer crane control from top to bottom (block #1)	8:28 AM	4 mins
Lower Block #1 below ceiling height of tunnel	8:29 AM	1 min
unload block #1 from crane hook	8:32 AM	3 mins
crane hook raised above ceiling (block #1)	8:33 AM	1 min
secure block #1 on forklift	8:37 AM	5 mins
Transfer crane control from bottom to top (block #1)	8:37 AM	4 mins
move block #1 past fire doors	8:38 AM	1 min
close fire doors at bottom of ramp (block #1)	8:39 AM	1 min
transport block #1 to Absorber Cavern	8:44 AM	5 mins
crane hook returns to surface (block #1)	8:46 AM	9 mins
Load Block #2 on crane at top of shaft	8:51 AM	5 mins
unload block #1 in Absorber Cavern	8:54 AM	10 mins
return from Cavern to bottom of shaft (block #1)	8:59 AM	5 mins
Lower Block #2 down shaft	9:00 AM	9 mins
open fire doors at bottom of ramp (block #1)	9:00 AM	1 min
move fork lift past fire doors (block #1)	9:01 AM	1 min
Move block #3 from hardstand into SB	9:03 AM	10 mins
Transfer crane control from top to bottom (block #2)	9:04 AM	4 mins
Lower Block #2 below ceiling height of tunnel	9:05 AM	1 min
unload block #2 from crane hook	9:08 AM	3 mins
crane hook raised above ceiling (block #2)	9:09 AM	1 min
secure block #2 on forklift	9:13 AM	5 mins
Transfer crane control from bottom to top (block #2)	9:13 AM	4 mins
move block #2 past fire doors	9:14 AM	1 min
close fire doors at bottom of ramp (block #2)	9:15 AM	1 min
transport block #2 to Absorber Cavern	9:20 AM	5 mins
crane hook returns to surface (block #2)	9:22 AM	9 mins
unload block #2 in Absorber Cavern	9:30 AM	10 mins
return from Cavern to bottom of shaft (block #2)	9:35 AM	5 mins
Put block #1 in place in Absorber Cavern	9:54 AM	60 mins
Put block #2 in place in Absorber Cavern	10:30 AM	60 mins



- blocks to Minos SB via Support Services
- 3 man-crew on surface
- 3 man-crew underground
- 36 minutes to get block into Cavern (45 minutes used in estimating costs)

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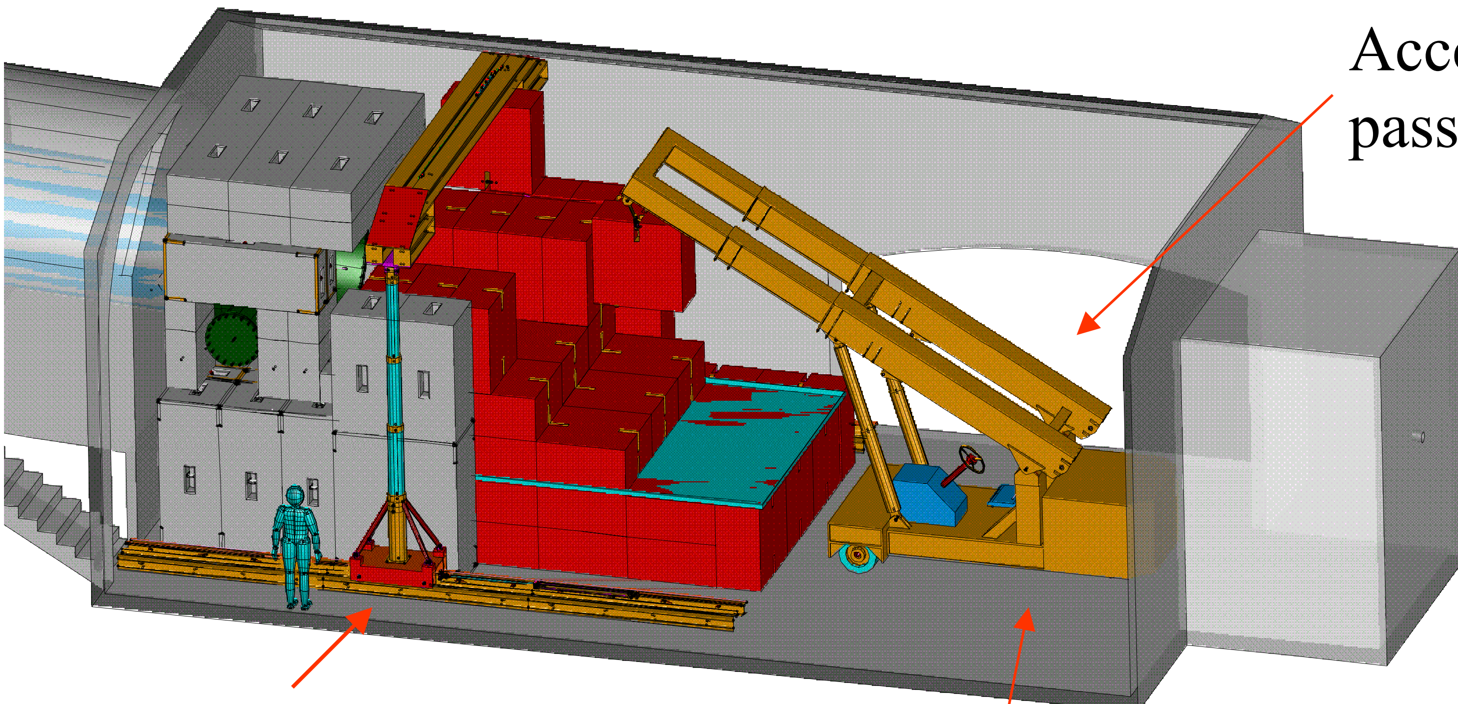
Installation in Cavern

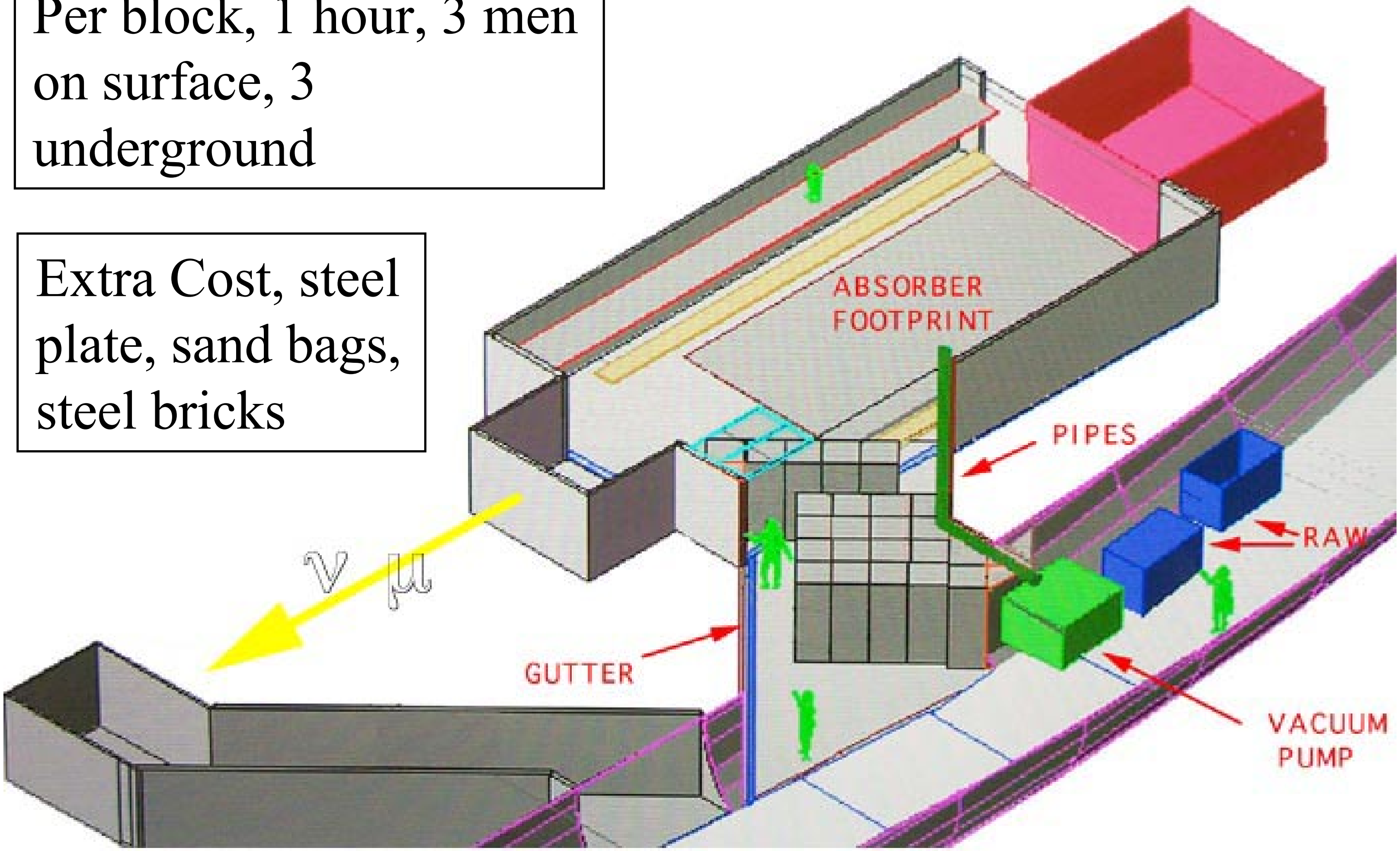


Cost estimate uses 3 man-crew, 1 hour to put block into place in Cavern

Labyrinth Installation Cost

Per block, 1 hour, 3 men on surface, 3 underground

Extra Cost, steel plate, sand bags, steel bricks



Summary

- after this review: further engineering of installation equipment, techniques, absorber components, US shielding arrangement, etc.
- refinement of cost estimate by 7/15
  - due to DOE by 7/31
  - focused DOE Review of WBS 1.1 on 8/22-24
- MARS studies with actual geometry (for updated groundwater activation, residual radioactivity, labyrinth source term, etc.)

Coming Next

- Nancy Grossman -- radiation safety issues
- Ernie Villegas -- engineering issues
- Bob Wands -- thermal studies (for accident condition of full beam power)
- Bob Ducar -- RAW cooling system (and beam permits)
- Bruce Baller -- installation integration issues
- Summary of presentations & interactions with committee